Census Sampling Confusion

Controversy dogs the use of statistical methods to adjust U.S. population figures

By IVARS PETERSON

Counting the number of people in the United States is a massive, costly enterprise, done once every 10 years.

For the year 2000 enumeration, the Bureau of the Census plans to mail out more than 90 million questionnaires and deliver millions more by hand to households across the nation before Census Day, April 1. An army of census takers will next fan out across the country aiming to track down the significant number of people who fail to return forms.

Past experience suggests that, despite such a huge effort, the population count will still be incomplete. In 1990, the Census Bureau officially recorded 248,709,873 people. Evidence from other surveys and demographic analyses indicated that the population was closer to 253 million and those not counted were mostly children, people from racial and ethnic minorities, and poor residents of both rural and urban areas.

"Coming out of the 1990 census, we recognized that you can't count everyone by direct enumeration," says Barbara Everitt Bryant, Census Bureau director during that head count.

To obtain the most accurate count possible in the year 2000, the Census Bureau has proposed integrating the results of conventional counting techniques with the results of a large sample survey of the population (SN: 10/11/97, p. 238). Bureau officials call this approach a "one-number census" because the statistically adjusted result will be the one and only official count.

"The plan will help lead to a result that includes more of the overall population, especially for certain subpopulations, and it will help to control costs," Tommy Wright, chief of the Census Bureau's statistical research division, argues in the Jan. 22 SCIENCE.

In January, however, the Supreme Court ruled against the use of statistical sampling methods to obtain population figures for determining how many of the 435 seats in the House of Representatives go to each of the 50 states. At the same time, the court upheld a law that mandates the use of statistically adjusted figures, when feasible, for all other purposes, such as distributing $180 billion in funds for federal programs and determining congressional and state district boundaries.

Last week, the Census Bureau responded to the court's decision and unveiled a revised plan for Census 2000 that would, in effect, provide two population totals. After counting "everyone it possibly can," the bureau would then conduct a quality-check survey, says Kenneth Prewitt, Census Bureau director. The new plan, however, could push the cost of conducting the census from $4 billion to more than $6 billion.

A handful of statisticians has also entered the fray. David A. Freedman of the University of California, Berkeley; Martin T. Wells of Cornell University in Ithaca, N.Y.; and several colleagues contend that current survey techniques don't necessarily provide the accuracy needed to improve census data.

"It's a very difficult problem," Wells says. "There are many, many problems for which statistics is wildly successful, but statistics can't solve everything." Freedman and his colleagues present their critique in a paper posted on the Internet (Technical Report 537 at http://

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Census year	Total U.S. population (millions)	Number of enumerator staff	Number of headquarters and/or office staff	Total cost of census (thousands of dollars)
1790	3.9	650	[a]	$44
1800	5.3	900	[a]	66
1810	7.2	1,100	[a]	178
1820	9.6	1,188	[a]	208
1830	12.9	1,519	43	378
1840	17.1	2,167	28	833
1850	23.2	3,231	160	1,423
1860	31.4	4,417	184	1,969
1870	38.6	6,530	438	3,421
1880	50.2	31,382	1,495	5,790
1890	63.0	46,804	3,143	11,547
1900	76.2	52,871	3,447	11,854
1910	92.2	70,286	3,738	15,968
1920	106.0	87,234	6,301	25,117
1930	123.2	87,756	6,825	40,156
1940	132.2	123,069	9,987	67,527
1950	151.3	142.962	9,233	91,462
1960	179.3	159,321	2,960	127,934
1970	203.2	166,406	4,571	247,653
1980	226.5	458,523	4,081	1,136,000
1990	248.7	510,200	6,763	2,600,000

[a]There was no official headquarters staff for the first four censuses. In addition, the records for the 1790, 1800, and 1810 censuses were accidentally destroyed; the numbers shown are estimates.

Growth of the decennial census from 1790 to 1990.

www.stat.berkeley.edu/tech-reports/).

Many other statisticians disagree with that stand. "You have to look at what else is feasible," says David S. Moore of Purdue University in West Lafayette, Ind. "The real question is, Given the time constraints, the obvious weaknesses in straight enumeration, and the budget Congress is likely to supply, how good a job does the Census Bureau's proposed method do?"

"Generally, the statistical community is very much in favor of trying to do sampling," says Donald B. Rubin of Harvard University.

To illustrate the difficulties of obtaining accurate population figures, Wright uses an analogy. Suppose 10 enumerators, working independently, are asked to determine the number of people at a basketball game during halftime.

The ticket sales count won't do because some people might have sneaked in or legitimately gained admission without tickets, while others who bought tickets may not have shown up. Counting people in the stands during halftime presents other problems. Spectators come and go, some exiting the arena and others seeking refreshments or switching seats.

As a result, some people may be counted twice and others missed completely. Almost certainly, the 10 enumerators would come up with 10 different counts. That variability represents what statisticians call measurement error.

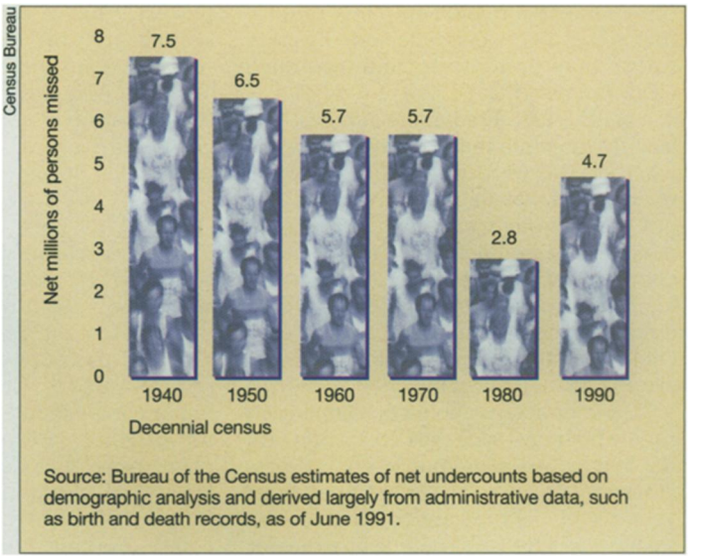
Just like the estimates of attendance at a basketball game, censuses of the United States also contain measurement error, Wright says. Moreover, given limited resources, it's difficult to keep that measurement error small when counting a large and highly mobile population.

As a quality check on the accuracy of the year 2000 enumeration, the Census Bureau has proposed surveying a nationwide sample of about 10,000 randomly selected areas, or "blocks," containing about 300,000 households. The Census Bureau divides the United States into roughly 7 million blocks, of which about 5 million are inhabited. A block can be just one large apartment complex or a rural county.

In an effort entirely independent of the main count, census workers would knock on the door of each housing unit in the sample blocks and list every person who admits to having resided there on Census Day. The Census Bureau would compare the results from the main count conducted in those blocks with this second, independent count, looking for matches of housing units and persons. Those two measures would then be combined to yield a single set of numbers.

The venerable, widely used statistical procedure that underlies this approach is known as the capture-recapture method. In effect, it combines two estimates, both slightly off from the true value, to generate one number that is thought to be closer to the truth than either of the original measures.

To illustrate how the technique works, consider the problem of estimating the number of perch in a certain lake. By fishing simultaneously in several areas distributed across the lake, a research team catches, tags, and releases 40 perch. That represents the capture phase.



The net undercount since 1940.

In a second effort, the recapture phase, the team goes out and catches, say, 50 perch, of which eight are tagged. Because one-fifth (8 out of 40) of the tagged fish were caught, you can conclude that this time approximately one-fifth of all the perch in the lake were caught. That means the total number of perch is about 250 (40/8 x 50).

In the Census Bureau's approach, the traditional count is the capture phase and the survey is the recapture phase. The final population estimate would be the product of the first measure (based on counting) times the second measure (based on sampling) divided by the number of people found in both phases.

"Although sampling techniques introduce sampling error, they offer the opportunity to diminish the larger measurement error and hence the overall error," Wright notes.

That approach has been endorsed by the National Research Council's Committee on National Statistics as well as a panel of the American Statistical Association and other groups.

"Estimation based on statistically designed samples is a standard and widely used method of obtaining information about large human populations," Moore says. All the economic indicators and employment figures, for example, stem from such methods.

Though there may be questions about the details of how the Census Bureau might implement statistical sampling, proper use of this tool can improve the accuracy of the census, Moore maintains.

It's the details, however, that bother Freedman and his associates. "Adjustment adds layer upon layer of complexity to an already complex census," the statisticians contend. "The results of adjustment are highly dependent on somewhat arbitrary technical decisions. Furthermore, mistakes are almost inevitable, are very hard to detect, and have profound consequences."

Flawed data processing and clerical work in both the census and the survey, for example, can accidentally introduce errors. In the 1990 quality-check effort, a computer glitch would have mistakenly added a million people to the initial count.

If they go undetected, such errors can have a significant impact. The census includes both overcounts (people erroneously counted twice) and undercounts (people missed). The quality-control survey provides estimates of both numbers. However, a relatively small error in approximating the number of omissions and the number of mistaken enumerations could lead to an unacceptably large error in calculating the difference of the two, the net undercount.

Even if it's possible to improve the counts of demographic groups across the nation as a whole using sampling, critics of the method point out that getting an accurate estimate of the population make-up in an individual state, county, or city is much more difficult. That's important because political representation and tax funds are generally allocated to geographical areas rather than specifically to racial, ethnic, or other groups nationwide.

Some groups of people, such as children, are likely to be missed in both the census and the follow-up survey. Other people, such as college students, may get counted twice. The difficulty is that the people missed or counted twice aren't distributed evenly across the country but are concentrated in different regions.

"Unless the adjustment method is quite exact, it can make estimated shares worse by putting people in the wrong places," the statisticians point out.

In planning for the 2000 census follow-up, the bureau has responded to criticisms of the 1990 post-enumeration survey, which was not actually used to adjust the 1990 counts. It intends to increase the sample size substantially, change the procedure for matching

the enumeration and sampling, require that adjustments be made state by state rather than nationwide, and introduce other refinements.

Nonetheless, Freedman and his colleagues maintain that the central issue is whether the proposed adjustments to the census take out more error than they put in. Although sampling error goes down as the sample size increases, it becomes more difficult to recruit, train, and manage the personnel required to conduct an accurate survey, they contend. Other potentially sizable, hard-to-detect errors can then creep in.

"Those concerns about nonsampling error are not new," says the Census Bureau's Raj Singh. "We have quality-control programs, we monitor the various operations very closely as they are conducted, and we have an extensive training program for the staff performing those operations."

"The Census Bureau does an outstanding job, but it has constraints," Wells says. "There's no easy solution. You have to be very careful and try to really understand where the problems lie."

"This is a scientific question on which scientists ought to be able to use their best judgment without being attacked for the consequences of that judgment on, for example, apportionment or representation of minorities," Moore says. However, "that doesn't mean that the scientists have to be unanimous."

The method also doesn't have to be perfect. "You're correcting the big errors," Bryant says. "The whole point of the adjustment is to get the differential undercount down."

	1980	1990
Population distribution (percentage)		
White (non-Black)	79.9	75.7
Black	11.5	11.8
American Indian, Alaska Native	0.6	0.7
Asian Pacific Islander	1.6	2.8
Hispanic	6.4	9.0
Net undercount estimates (percentage)		
White (non-Black)	0.8	1.3
Black	4.5	5.7
American Indian, Alaska Native	NA	4.5
Asian Pacific Islander	NA	2.3
Hispanic	NA	5.0

Note: NA = Not available

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Changes in the U.S. population and its undercount by race and ethnicity between the 1980 and 1990 decennial censuses.

Dress rehearsals last year allowed the Census Bureau to test and refine its procedures. For example, the bureau implemented its original census plan, which includes statistical sampling for completing the count and for conducting an independent post-enumeration survey in Sacramento, Calif. There, the initial population count was 349,197. Door-to-door enumerators and sampling techniques later added 28,544 people. The independent quality-check survey pointed to a net undercount of 6.3 percent, even after the additions. The final, adjusted population figure was 403,313.

In Columbia, S.C., and 11 surrounding counties, the Census Bureau conducted the dress rehearsal using only traditional counting methods and came up with a population total of 662,140. It also administered a post-enumeration survey to check accuracy but not to make an adjustment. The survey indicated that the count missed 9.4 percent of the population. The net undercount was 13.4 percent for blacks and 6.3 percent for whites.

"The evidence, repeatedly from the first census through the 1990 census, suggests that if Census 2000 were conducted . . . using the conventional methods of the past, even with increased outreach, the results would tend to be consistently below the truth," Wright insists. "On the other hand, theory, simulations, and tests lead us to believe that a one-number census . . . would tend to yield results around and closer to the truth."

The debate over sampling in the census, however, is far from over. In Congress, it has become a highly partisan battle.

Republicans vehemently oppose the use of sampling. They favor improving the traditional head count. Their proposal makes additional funds available to the Census Bureau to reach a greater number of people by advertising the census more widely, hiring extra census workers, and translating the census forms into additional languages.

Congressional Democrats strongly support the Census Bureau's original plan and are ready to go along with the Clinton administration's idea of pursuing an enumeration that produces two sets of figures. Some contend that, without sampling, the bureau will get a significant undercount no matter how much it spends on outreach.

With funding for the Census Bureau slated to run out in June, reaching a decision on the specific form the census will take becomes a major issue.

"The census is a very large undertaking," Moore says. "With Congress not wanting to fully fund the census until these issues are settled, regardless of which way we go, [Census 2000] may end up being seen as a failure simply because there wasn't enough time to do all the details as well as we would like." □